Field Performance and Mitigation of Shredded Tire Embankment

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The design, construction, and mitigation of a shredded tire embankment that underwent pyrolysis and full combustion are discussed. The embankment was constructed to repair a 45-m-long section of SR-100 near Ilwaco, Washington, after a landslide occurred in native weathered siltstone. Because of foundation soil characteristics and the proximity of environmentally sensitive areas, the roadway was rebuilt using shredded tires as a lightweight embankment material. Construction of the 8-m (maximum depth of shredded tire chips) embankment went smoothly. Less than 2 months after completion, however, unusual asphalt cracking, odors, and steam were observed in the embankment. The steam and elevated surface temperature readings suggested pyrolysis or combustion of shredded tire chips. Weekly monitoring and sampling were conducted while mitigation options were evaluated. Less than 4 months following construction, an oily substance was observed in the water seeping from the drainage blanket underlying the embankment. The oil was immediately contained using booms, sumps, and a containment berm. Because exposure to oxygen could cause a flare-up, several in situ cooling methods were evaluated to minimize oxygenation of the material. Because of environmental and logistical concerns, excavation and water immersion of shredded tire chips was deemed the preferred mitigation measure. If using shredded tire chips as an embankment material is to be continued, it will be necessary to identify factors contributing to the pyrolysis/combustion so that preventive design criteria can be developed, and methods for remediating pyrolysis and combustion problems should they arise.

In December 1994, a landslide occurred in native siltstone underlying a portion of SR-100 near Ilwaco, in southwestern Washington State, which removed approximately 45 m of two-lane roadway to a depth of 6 m below the preexisting roadway surface. The roadway was rebuilt using shredded tires as a lightweight embankment material and subsequently underwent severe degradation resulting from exothermic reactions occurring within the tire mass.

This paper presents data collected at this site after the initiation of pyrolysis and combustion and discusses the use of shredded tires at the site, from design and construction through excavation and mitigation.

SITE DESCRIPTION

The landslide occurred within the boundaries of Fort Canby State Park, at the mouth of the Columbia River in southwestern Washington (Figure 1). Bedrock near the slide is composed of dark gray to olive gray tuffaceous siltstone and sandstone of the early Oligocene–late Miocene Lincoln Creek Formation. The rock has been deeply weathered, resulting in residual soil thicknesses of up to 8 m. The residual soil is composed of medium dense to dense, mottled, brown-gray, blocky sandy silt, silty sand, and elastic silt. The roadway alignment trends generally north-south through the project area. The headscarp of the slide was located approximately 25 m west of the preexisting centerline; the toe of the slide was approximately 98 m east of the centerline. The landslide toe was intruded onto the tidal salt marsh of the Columbia River estuary. Overall vertical relief between the headscarp and toe of the slide was approximately 34 m.

Rainfall in southwest Washington averages 1400 mm/year, falling mostly from November through March. The average temperatures do not vary much throughout the year, with a high average in August of 14.8°C to a low average in January of 5.7°C. Water was observed emitting in seeps from the base of the headscarp area and running in streamlets down the slide debris to the tidal flats. A slight artesian flow of approximately 2 L/min was encountered at elevation 14.3 m in one test boring.

INVESTIGATION AND LABORATORY TESTING

Subsurface investigation included five geotechnical test borings. Standard penetration tests (SPTs) were performed at 1.5-m intervals and disturbed, Washington undisturbed, and Shelby soil samples were obtained. Rock cores were obtained where bedrock was encountered. Two slope inclinometers were installed to monitor any subsequent ground movement.

Moisture content, grain size, and Atterberg limits were determined for selected samples. Unconsolidated, undrained tests were run on five samples, and one direct shear test was performed on a sample from the residual soil unit.

LANDSLIDE MITIGATION

Because of the relatively unsuitable nature of the foundation soils, geotechnical recommendations for remediation included two options:

1. Constructing an embankment with a shear key and conventional fill, or
2. Constructing an embankment using scrap tires as a lightweight embankment material.

Option 2 was chosen because (*a*) it was the least costly, (*b*) it would cause the least impact to adjacent wetlands and forest lands, and (*c*) scrap tire use was encouraged by environmental and resource agencies.

Option 2 called for removing 1 to 1.5 m of loose, saturated slide debris from the base of the slide. To keep the shredded tire mass above the water table, a 1.2-m rock drainage layer would replace excavated debris. The bulk of the embankment would be constructed

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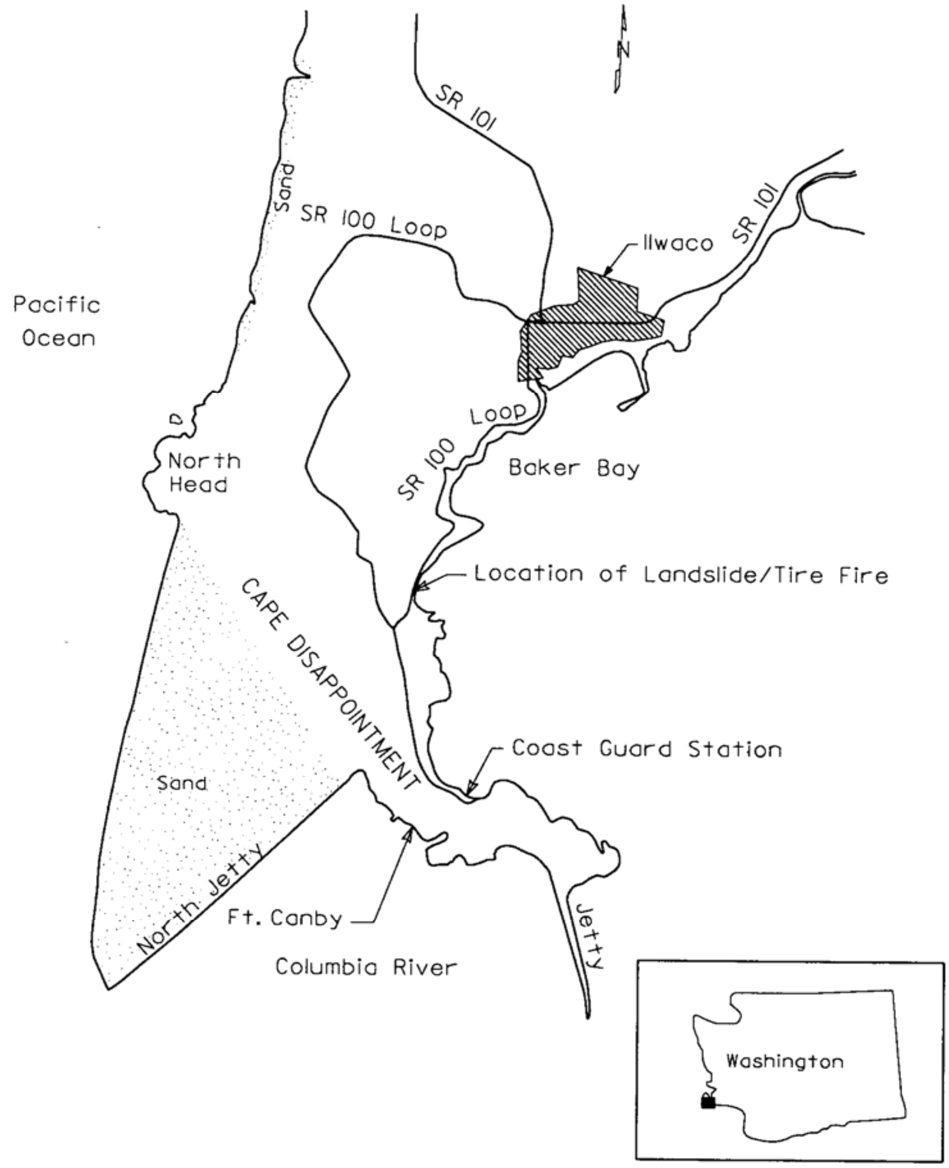

FIGURE 1 Vicinity map.

with shredded tires. It was recommended that a 1.2-m depth of gravel borrow material cap the shredded tires, with 0.3-m cover on the sideslopes (Figure 2).

EMBANKMENT CONSTRUCTION

During construction (September 25 to November 2, 1995), recorded rainfall was 314 mm. Because of the instability of the weathered siltstone and limited access, the foundation was prepared using cranes and dragline buckets. The drainage layer was placed by end dumping material from the existing pavement until sufficient mass was in place to allow access to the floor of the slide with a bulldozer. Subsequently, a bulldozer spread and graded the material to the specified thickness.

The shredded tires were also placed by end dumping. The shredded tire chips varied in size from 51 to 152 mm. They were composed of sheared and ripped fragments. There is no supporting documentation, however, to determine the percentage of sheared versus ripped tire chips. Substantially more exposed steel belts were evident with the ripped fragments. Some truck tire components were observed. They were spread uniformly in 0.3-m lifts with a bulldozer; each lift was compacted by at least one pass with a tracked vehicle. Construction of the shredded tire fill was staged with the placement of a geotextile for soil stabilization and soil cover in approximately 6-m segments. The tire chip fill slope was trimmed with a track-mounted backhoe.

Approximately 5400 m^3 of shredded tires (approximately 700,000 tires) are used to construct the fill. Construction cost was $544,901.

PROBLEMS

Construction of the embankment occurred with very few problems. There was slight settlement (60 mm) during final trimming of the subgrade, which was assumed to result from the additional load of gravel borrow, surfacing, and pavement.

On December 28, 1995, an unusual longitudinal crack, approximately 23 m long and several centimeters wide, was observed at the

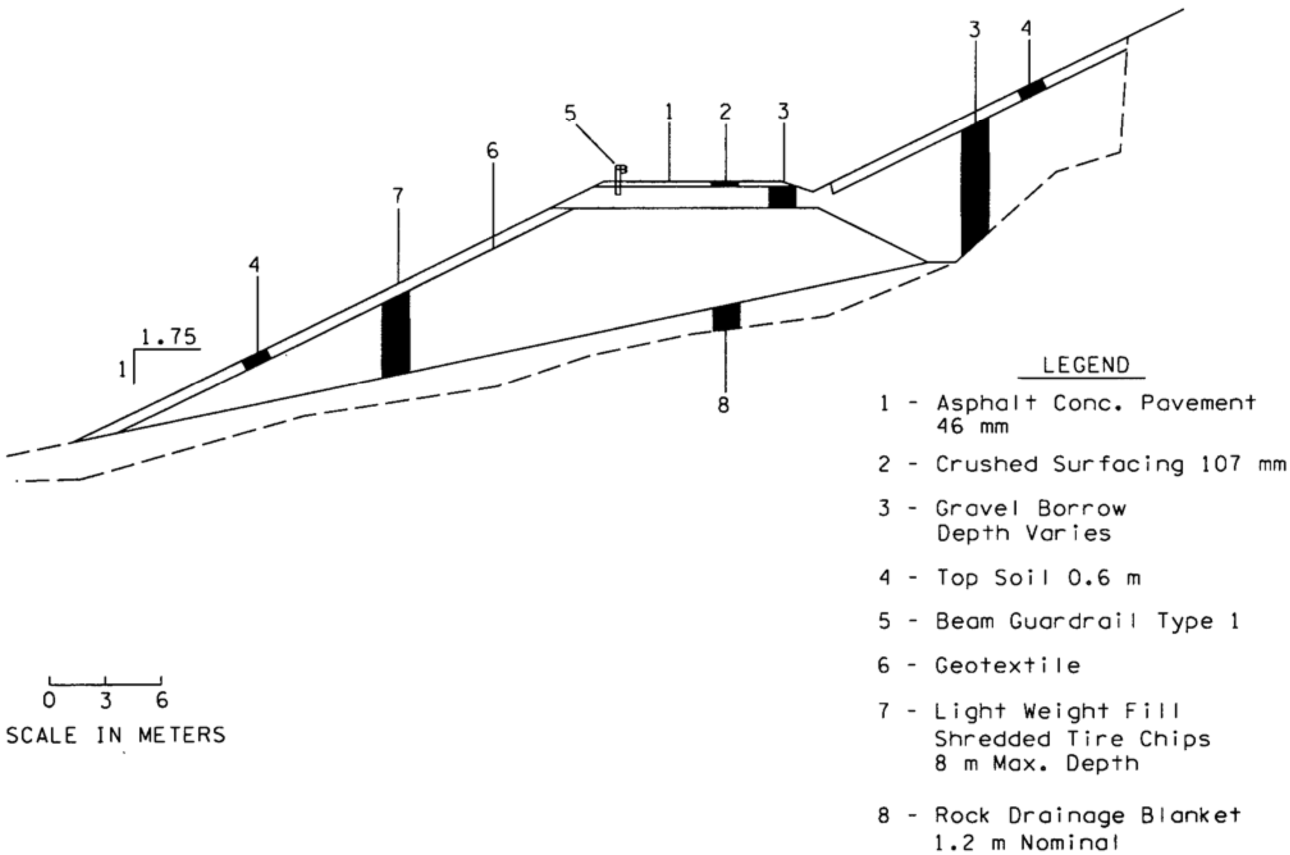

FIGURE 2 As-built section.

centerline pavement joint. Additional cracks were observed along the gravel roadway shoulder near the guardrail. On January 3, 1996, steam was observed emitting from the cracks. The ground adjacent to the cracks was dry, although it had rained and all other surfaces were wet. A thermometer inserted into one of the cracks read 68°C, the highest temperature the thermometer could record. No settlement of any part of the embankment was detected visually. However, on January 6, 1996, this section of SR-100 was closed because of concerns over roadway stability and air quality.

A monitoring program was initiated that included settlement surveying, surface temperature monitoring, and air and water quality monitoring. The maximum surface temperature measured was 73.8°C.

On February 11, 1996, the exposed part of the rock drainage blanket at the base of the embankment was covered with plastic, and water flowing from the drainage layer was channeled into two 102-mm PVC pipes that were submerged into a sump to block oxygen flow to the tires.

In late February and early March, the settlement rate increased significantly, and cracks formed around the perimeter of the tire chip embankment. The Washington State Department of Transportation (WSDOT) determined that the shredded tire chip fill had to be removed and hired an environmental engineering consulting firm to provide recommendations.

EMERGENCY RESPONSE

On March 14, 1996, oil was observed seeping with groundwater into the sump at the outflow of the rock drainage blanket. The Washington State Department of Ecology (WSDOE), which administers Washington's oil spill contingency plan, was notified, and WSDOT's spill response contractor began cleanup within 4 hr of the discovery.

A system of three small, lined detention ponds was installed to collect, separate, and absorb oil. Absorbent snares were placed in the lower sumps to collect any remaining sheen. Two sorbent booms were placed (Figure 3) to capture oil that had escaped to the saltmarsh area. With each tide change, oil was lifted from the marsh grass, contained by the booms, and passively sorbed with polyester snares.

When additional oil appeared in sediments outside the berm (within the tidal booms), WSDOE voiced concern that oil might pool within the drainage blanket and that the hydraulic head of such a pool could push oil downward into a deeper water table. Historical data showed that the drainage blanket was on a uniformly graded clay surface, freely draining from the toe of the headscarp to the lower limit of the drainage blanket. However, to alleviate concern, WSDOT trenched out the first detention pond nearest the toe of the slope to expose subsurface soils, and placed an interceptor trench outside the berm. Neither excavation revealed any subsurface oil, ruling out the possibility of a large ponding of oil.

Oily Water Recovery and Contingency Containment

To prevent the occurrence of an unrecoverable oil discharge, WSDOT contracted with Quigg Brothers–Schermer, Inc. to construct contingency measures (based on the volume of tire chips, it was determined that the tire chips had the potential to produce up to 6 704 600 L of oil).

FIGURE 3 Embankment excavation with berm and sorbent booms in background.

An access road to the toe of the fill was built to facilitate construction of a containment berm. Because of restrictions imposed by severe topography and adjacent old-growth conifers, the road was on a 38 percent gradient, preventing the use of dump trucks for hauling supplies and materials. Fill materials were pushed with a small bulldozer, and other materials were transported by track excavator and a skiff box.

A semicircular containment berm was then constructed around the oil collection sumps, oil storage reservoir, and toe of the embankment. The berm was approximately 2 m high and had a maximum holding capacity of 378 500 L. Its inward and top surfaces were sealed with a 40-mil PVC welded-seam lining to ensure that all potential contaminants were contained.

On April 2, 1996, water sampling showed elevated levels of toluene and cyanide, resulting in the immediate suspension of all discharge from the project. Baker tanks (with a holding capacity of 83 270 L each) were mobilized to store groundwater pumped from the lower interceptor trench. Nineteen Baker tanks were needed to contain runoff and provide contingency backup for storing runoff from the project, due primarily to heavy rainfall.

A temporary stockpile site was constructed to store potentially contaminated materials excavated from the fill. The floor of the stockpile area was designed to retain and collect all potential contaminants that might leach from stored materials. It consisted of a uniformly graded and compacted native weathered siltstone base, a 152-mm cushion layer of fine beach sand, a 40-mil PVC welded seam liner, and a 152-mm cushion layer of fine beach sand topped with crushed rock for vehicle traction. The estimated capacity was approximately 7646 m^3.

Evaluation of Chip Cooling and Removal Options

While oil was being collected, WSDOT evaluated alternatives for remediating hot spots prior to excavation. The alternatives evaluated were as follows:

1. *Do nothing (allow embankment to continue burning).* This alternative would allow the tire chips to continue burning until all fuel was spent. This implied continued anaerobic pyrolyzation or combustion of the materials. This alternative was not chosen because of its risks: (*a*) proximity to local residents raised human health concerns, (*b*) oil would continue to be produced and have to be contained and collected for an undetermined period of time, and (*c*) at least a portion of Fort Canby State Park would have to remain closed through the summer and possibly into the following year.

2. *Isolate and accelerate hot spot burning (allow embankment to continue burning).* This alternative would excavate and remove material over the tire chips and around the hot spot areas so the fire could burn aerobically, speeding up the burn. This would result in more complete combustion of tires and gases. Alternative 2 was not selected for the same reasons listed under Alternative 1, and for the additional fact that it would increase the fire hazard to nearby virgin old-growth trees.

3. *Quench burning material in place.* This alternative would extinguish the fire in situ prior to excavating the cover materials or the tire chips themselves. Horizontal drill holes fitted with perforated casing would provide conduits for the quenching medium. Possible tire-suppressing media included cryogens (liquid carbon dioxide or nitrogen) and water mixed with synthetic fire suppressants. The partially extinguished or quenched material would then be removed from the embankment. This option was not selected because (*a*) it was not possible to assess the thoroughness of infusion until the embankment was excavated; (*b*) thorough infusion was not expected, because as the surface of a heated, degraded chip is cooled, it crusts over, preventing contact with the rest of the hot material; (*c*) surfactants would emulsify oils, rendering the detention ponds useless for oil collection; and (*d*) many surfactants are highly toxic.

4. *Expose and quench with chemical surfactant in place.* This alternative was similar to Alternative 3 and would also expose the hot spot areas by removing the surrounding and overlying material, followed by quenching in situ. This method involved a more direct application of the fire suppressant agent by spraying the liquid onto the tire chips. Although it had the advantage of allowing visual verification of the quenching medium's effectiveness, this alternative was not selected because of the same problems with surfactants described under Alternative 3.

5. *Isolate, remove, and quench with water.* This alternative would remove the burning material using conventional excavation equipment. Material would be quenched at the point of removal and loaded into trucks for transport to a temporary holding area. This alternative was selected because (*a*) the quenching material (water) was the most environmentally sound medium and would not hurt the oil collection system, (*b*) the hazard to workers could be minimized by using large cranes to remove material remotely, (*c*) visual verification of efficiency was possible, (*d*) water had the lowest cost of any extinguishing material, and (*e*) contaminated water collected at the toe of the slope could be applied to the heated tire chips as a quenching medium.

Alternative 5 consisted of the following steps:

1. Remove overlying roadway and subbase material to expose underlying tire chips; begin to remove and transport unaffected tire chips.
2. Remove hot material by a crane-mounted clamshell and place it in a nearby quenching tank.
3. Remove cooled material from the quench tank with a modified bucket (slotted, to allow drainage).
4. Check temperatures with infrared sensor to ensure material is cool enough to be transported and stockpiled.

5. Transport material in trucks to an environmentally engineered holding area.
6. Spray water onto the area with fire hoses if flame is encountered during removal.
7. Collect all water used for quenching, pump it to Baker storage tanks, and reuse it for further quenching.
8. Allow tire chips to cool and subsequently truck them to a final disposal site.

IMPLEMENTATION OF PREFERRED EXCAVATION OPTION

Water and oil collection sumps and trenches were used to collect all quenching and surface runoff, as the existing topography naturally drained to these facilities (Figure 4). Water pumped to Baker tanks was stored and recycled for quenching and for controlling fire outbreaks. A 15-cm-diameter, 2800 L/min water pump was plumbed to the Baker tanks to provide water for firefighting. Water monitors (cannons) fitted with 6-cm supply line were strategically located as primary fire control. The local volunteer fire departments provided backup for tire fire suppression and furnished protection for the adjacent old-growth trees.

Quenching and removing the tire chips was done by (*a*) lowering the embankment surface to provide sufficient reach for the backhoe to excavate to the anticipated bottom of the hot spot, (*b*) removing the two known hot spots, and (*c*) removing the remaining unaffected chips Figure 5.

Infrared thermal imaging was used to locate the hot spots. The plan called for all excavation to be conducted by track backhoes (Figure 6) in the following stages:

1. Remove the headscarp backfill level with the pavement surface and remove the rail element of the guardrail.
2. Remove asphalt concrete pavement, crushed surfacing top course, and gravel borrow to approximately the top of lightweight fill and remove guardrail post; and test surface stability with the trackhoe bucket by point loading any area before placing equipment on it.
3. Remove approximately 1.6 m of tire chips.
4. Isolate the two distinct hot spots by removing unaffected chips around the perimeter and to the bottom of each hot spot; remove hot spots in a layered manner, controlling fire flare-up with suppression equipment; cool chips by immersing in a water bath as needed and spreading in a cooling/loading tray; and load and haul cooled material to the stockpile site.
5. Remove remaining unaffected chips and haul them to the stockpile site.

Oil recovery was measured, recorded, and plotted on a graph daily, and key events were annotated as they occurred. An immediate reduction in oil production was documented after the asphalt was removed (Figure 7). In other words, when the cover overlying the tires was removed, allowing free access to oxygen (and therefore allowing full combustion to occur), oil production dramatically and immediately decreased.

A visual inspection performed upon completion of Stage 3, and temperatures and tire chip samples taken from the lowered surface of the embankment (approximately 3 m below pavement elevation), revealed two things. First, all tire chips at this level of the embankment had experienced some degree of pyrolysis as evidenced by the bonded condition of the chips, apparently resulting from thermal degradation. Vents approximately 0.6 m in diameter with varying levels of emissions were noted at four locations near the hot spots. Tire chips in the vicinity of the vents had undergone significant pyrolysis, appearing very black and having a charred appearance. Residues on the edges of chips varied from a white ash-like substance (south hot spot) to an orange crystalline substance (north hot spot). Except at apparent vents, chips were medium brown or rust in color. Tire

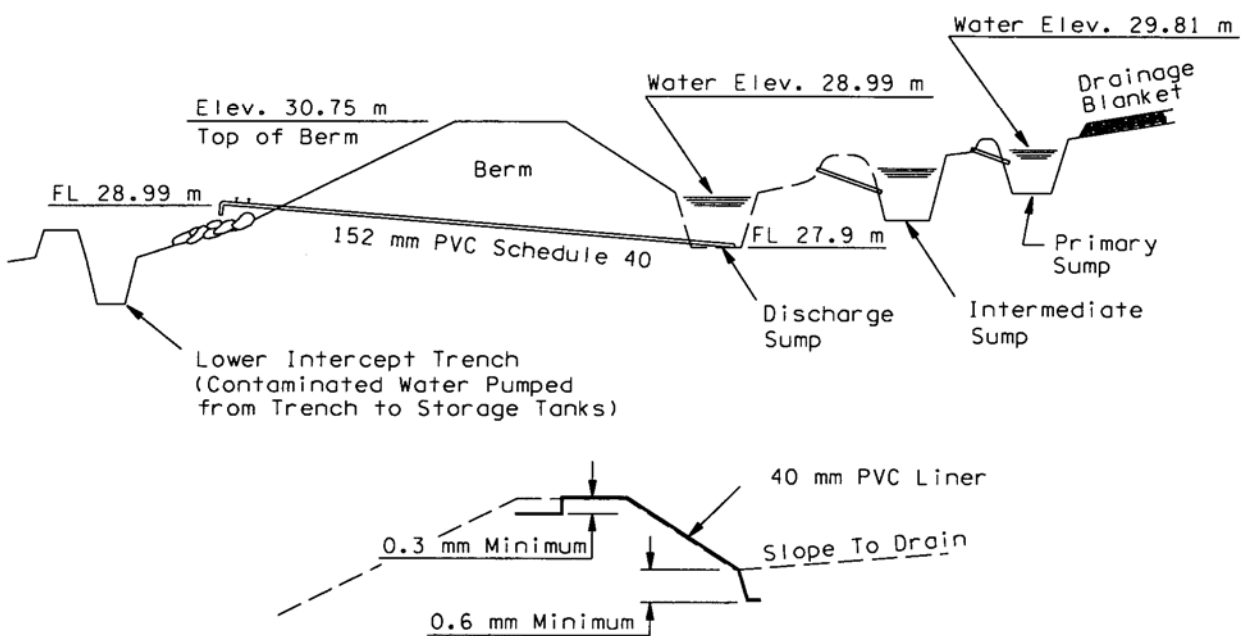

FIGURE 4 Oil separation–water containment system (*top*); containment berm detail (*bottom*); all sumps and intercept trench lined with 10-mil polyethylene sheeting.

FIGURE 5 Removal of unaffected chips.

chip samples taken at several locations showed varying degrees of pyrolysis. Second, surface temperatures varied from 50°C to 78°C. The highest readings were observed at the vent locations.

Observations made during the surface inspection and excavation to this depth established confidence that the remaining excavation could be performed safely using trackhoe excavators.

At approximately 10:00 p.m., April 7, 1996, fire broke out on the surface of the shredded tire embankment near the north hot spot, in an area approximately 10 m in diameter, with flames rising approximately 2 m above the fill surface. The Ilwaco Volunteer Fire Department extinguished the fire with little effort. Several small flare-ups occurred intermittently at the vent locations; these were controlled with minimal misting. These flames were the result of gas emissions and oil (products of pyrolyzation) igniting, rather than tire chip combustion.

On April 8, 1996, construction of the isolation trenches for the south hot spot was begun as described in Stage 4 of the excavation plan. Shortly after the first trench was excavated, to a depth of approximately 7 m, the bottom and walls of the trench began burning. Out of concern for worker safety and possible damage from continued flare-ups to hydraulic-actuated equipment, all further excavation was performed using cranes equipped with a clam bucket. Access to the tire chip embankment was restricted until all combusting chips were removed.

Chips were clamshelled, moved to the cooling tray, lightly agitated in water, and removed by a track excavator equipped with a slotted bucket. Once chips were cooled to a maximum temperature of 32°C and drained, they were loaded into trucks. The highest recorded temperature before quenching was 185°C (restricted access permitted taking temperatures only after the material was placed in the cooling tray).

During excavation, two distinct hot spots were evident at the approximate locations where they had been predicted through visual observations and infrared imaging. The core of each hot spot was very near the bottom of the shredded tire chip mass, within the deepest section of the fill (approximately 8 m). After the tire chips and drainage blanket had been removed, reddish-brown to tan soil colors were observed immediately below the center of both hot spots. The tire fill embankment between the hotspots was entwined with veins of extensively pyrolyzed chips. The veins traveled primarily inward and up through the fill mass with some veins connecting the primary hot spots with chips pyrolyzing anaerobically. When exposed to oxygen, heated products of pyrolyzation in the veins ignited.

Once the main heat sources had been excavated, the remaining excavation was performed using conventional construction practices (track excavators and a small bulldozer).

A total of 13,938 tons of shredded tire chips, contaminated soil cover, drainage blanket, and native soils were excavated. They were temporarily stored in the stockpile site, loaded, and hauled to a solid waste disposal site. Another 402 tons of material were removed from the floor of the stockpile site and disposed of at the designated disposal site, as they contained elevated levels of benzo(a)pyrene. The total cost for disposal of the solid waste was $533,551.

Community Safety

An evacuation plan was prepared so that notification could be carried out quickly and efficiently in the event of an emergency. Emissions from the site were pungent, and several complaints were received from the public regarding air quality. As a result, four sites located 0.8 to 3.2 km from the project were monitored every 6 hr. Air quality at these locations never exceeded the acceptable minimum standards during monitoring.

Controlled Access

Access to the project was controlled with check stations at both site entrances, staffed 24 hr a day. All first-time visitors were required to read and sign the Site Safety Plan. All personnel arriving and departing were required to sign in and out, for three reasons:

1. To address the Washington State Parks Commission's desire to prevent damage to surrounding fauna,
2. To quickly provide accountability of all site personnel in the event of an emergency, and
3. To ensure the ability to relocate visitors to safe areas when air quality levels exceeded acceptable standards. Access was occasionally restricted to certified personnel when conditions required protective measures.

When chip excavation began, air monitoring frequency was increased and all visitors were briefed and accompanied by a safety officer.

Media

Media representatives were welcome and were encouraged to visit the project site. Press releases were provided daily, and public infor-

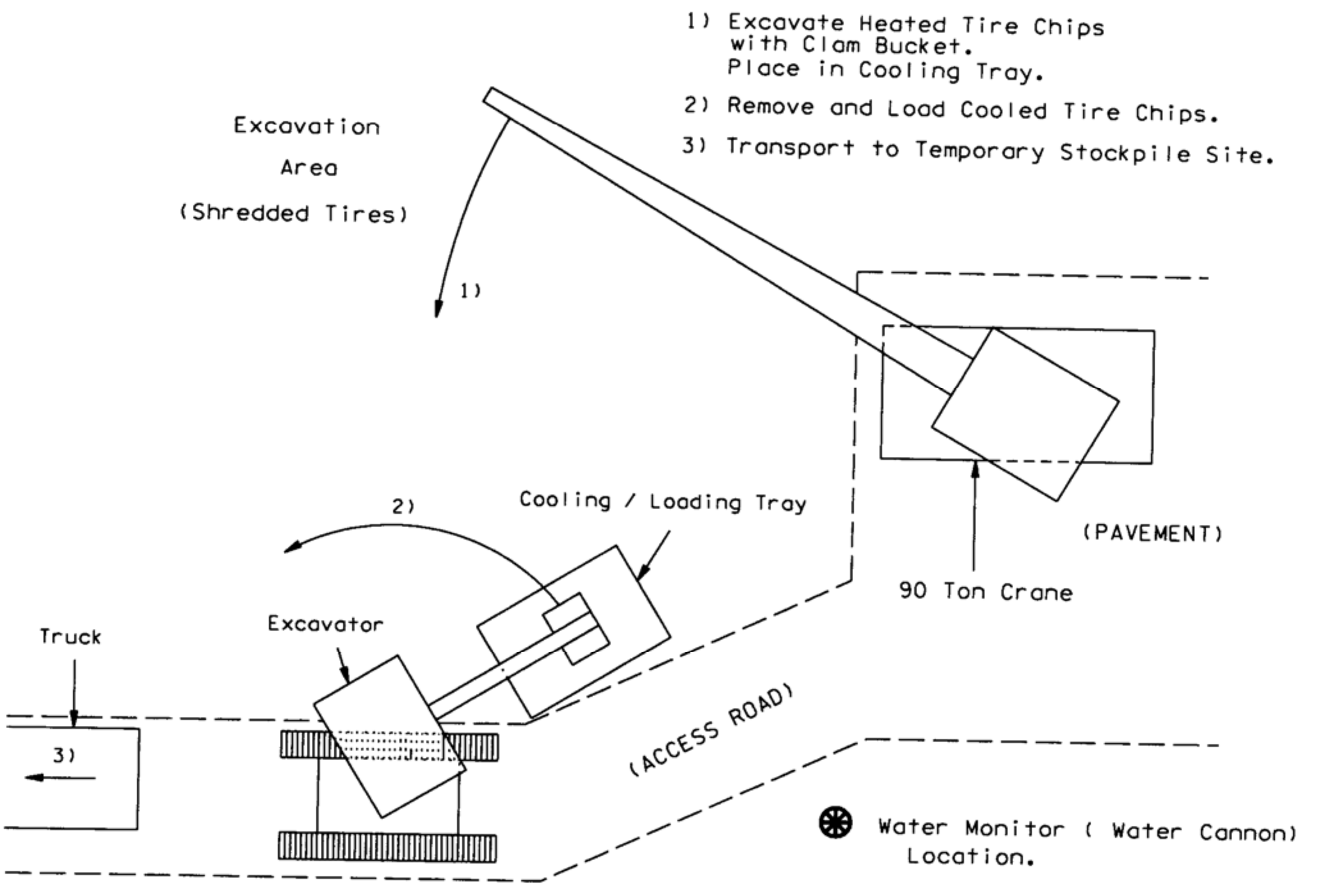

FIGURE 6 Plan view of excavation sequence.

mation officers were available to escort the media and answer questions. Two viewing sites were placed at key vantage points for the media and other visitors.

Worker Safety

Real-time monitoring for carbon monoxide using a combustible gas meter, total organics using a photoionizing detector, and benzene using Drager tubes was conducted before, during, and immediately after excavation. Monitoring was conducted both at the excavation site and in the staging area.

Exclusion zones were marked on the basis of air monitoring results. Levels D and C protective clothing was required in exclusion zones as appropriate. Level D requires steel-toed boots and hard hat. In some areas, protective clothing such as Tyvek was also required. In addition to Level D requirements, Level C requires air purification filter masks. Level B protective clothing was required for work carried out in areas that exceeded allowable limits for carbon monoxide. In addition to Level C requirements, Level B requires supplied air.

Workers in proximity to heated material were required to wear flame-retardant apparel as necessary. Heavy equipment operators were equipped with radios to facilitate communication in poor visibility. The local volunteer fire department had certified emergency medical technicians on site throughout all hot spot removal operations.

WASTE DISPOSAL

Oil Waste Disposal

Because the oil product leaching from the embankment was not a hazardous waste, all related materials could be disposed of as solid waste in a sanitary landfill. Protective clothing (PPE) and used sorb pads can be burned for energy recovery as hog fuel in industrial facilities. PPE and used sorbs were collected in two lined, 20-yd rolloff drop boxes. For acceptance at the industrial facility, the waste was rebagged and trucked to the facility in Longview, Washington, for incineration.

The oil leachate was amenable for blending into fuel for energy recovery. The oil was skimmed from the retention ponds, collected in a 24 600-L polytank, pumped to the top of the embankment into a 19 100-L transport, and trucked to an oil refinery in Portland, Oregon.

Water Disposal

Water not used for quenching was analyzed for metals, volatile organics, semivolatile organics, and cyanide. Elevated levels of benzene, phenol, toluene, and cyanide were detected. Because toluene evaporates rapidly, it was not a major concern at the levels detected. The highest detection level of cyanide was from the tank containing recycled quenching water. At 80 parts per billion (ppb), it was

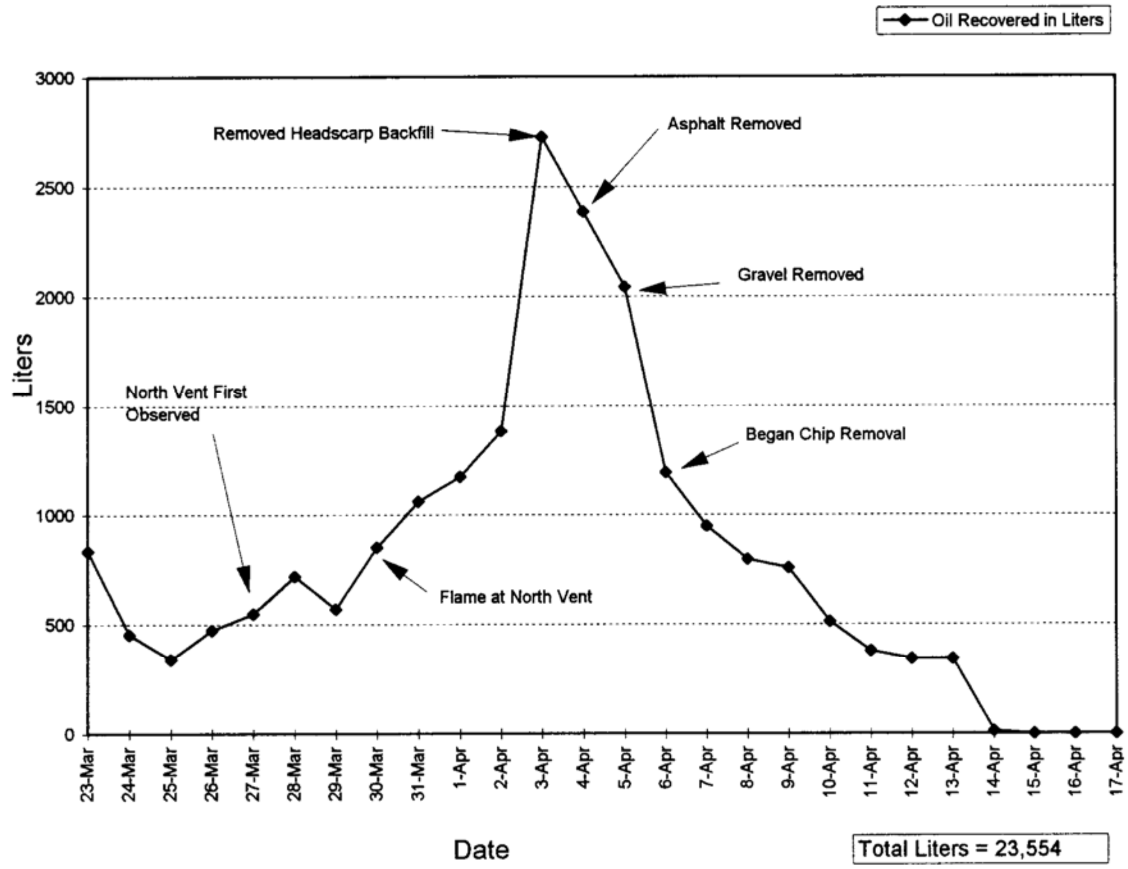

FIGURE 7 Oil recovery chronology.

significantly higher than the other tanks, which ranged between 2 and 5 ppb. The drinking water standard for cyanide is 200 ppb; however, the standard for Class A Marine Waters for fish protection is 1 ppb. Because there were no technologies for on-site treatment of cyanide capable of achieving the 1-ppb limit, the option for discharging the water directly to marine waters was ruled out.

Because the synergistic effects of the toxins identified were not known, WSDOT was required to run a trout bioassay on the waste water to determine whether it was a hazardous waste. The test sample was taken from the most contaminated tank and passed the bioassay, allowing WSDOT to consider options for discharging to a treatment facility.

Alternatives for disposing of the water were limited. The city of Ilwaco treatment facility did not have the capacity to accept the water. Trucking the water to the nearest facility that could accept it (Astoria, Oregon) was prohibitively expensive. A nearby permitted facility offered to accept the wastewater at no charge, and WSDOE granted approval for this disposal.

Tire Chip and Soil Disposal

WSDOT and other involved public agencies shared a preference for a beneficial recycled use for the waste chip material. Several options were considered for burning the chips for energy recovery; however, to use them for fuel, the chips would have to be reprocessed from 6 to 4 in. (15 to 10 cm). Storing the material was another obstacle to this option; the chips could be metered into hog fuel boilers only over the course of several months. Storing the chip material during that time would require a county-permitted stockpile area. For these reasons, burning chips for energy recovery was not considered a viable option.

To verify that the waste tire chips could be classified as solid waste, they were submitted to and passed a filter test. Several solid waste disposal facilities were willing to accept the waste chips, which could be combined with soil and applied as daily landfill cover.

Approximately 5352 m^3 of soil was removed from the area surrounding the tire chips. These soils were assumed to be slightly contaminated from contact with the adjacent burning tire chips and visible signs of petroleum. Because they could not be used for site reconstruction, they were hauled with the chips to the Hillsboro, Oregon, landfill.

SITE RESTORATION

Habitat Restoration Plan

Although environmental damage was minimal, some juvenile fish mortalities were observed, possibly caused by the oil spill. To address any damages, WSDOT worked cooperatively with resource agencies to restore the site to preslide conditions. This resulted in a signed agreement among the state and federal land trustees that provides for WSDOT to restore an approximately 1645-m^2 area to wetland conditions. The estimated cost to perform this work is $100,000.

Independent Cleanup Plan

WSDOT is preparing an independent cleanup plan (IRAP) consistent with requirements of the Model Toxics Control Act. The IRAP is being developed in conjunction with reconstruction of the roadway. Soil samples indicate that small amounts of benzo(a)pyrene remain beneath the fill. Benzo(a)pyrene is not toxic to fish, but it presents a human health concern if a person comes into direct contact with it. This concern will be alleviated by capping the soils, stabilizing them, and preventing any migration to surface waters.

Road Reconstruction

The road is to be constructed in fall 1996 using a shear key and rock embankment. The contract includes a wetland restoration plan requiring the excavation of 4116 m^3 of slide debris from the inundated saltmarsh.

CLOSING

If continued use of shredded tire chips as an embankment material is to be considered, it will be necessary to identify (*a*) factors contributing to the pyrolysis and combustion so that preventive design criteria can be developed; (*b*) methods for remediating pyrolysis and combustion problems should they arise; and (*c*) standards for quality acceptance levels of shredded tire chips, including minimum and maximum chip size, a specified method for reducing scrap tires to tire chips, and a test method to ensure that contaminants such as cyanide do not exist.

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